AN INTRODUCTION TO ENERGY STORAGE

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Sandia National Laboratories

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INTRODUCTION - SANDIA

Sandia is one of 17 U.S. National Laboratories

National Nuclear Security Administration labs

Science labs

Nuclear energy lab

Environmental management lab

Fossil energy lab

Energy efficiency and renewable energy lab

Sandia's National Security Mission

- Nuclear Deterrence
- Nuclear Nonproliferation
- National Security Programs
- Energy & Homeland Security
- Advanced Science & Technology

SANDIA HAS FACILITIES ACROSS THE NATION

Activity locations

- Kauai, Hawaii
- Waste Isolation Pilot Plant, Carlsbad, New Mexico
- Pantex Plant, Amarillo, Texas
- Tonopah, Nevada

Main sites

- Albuquerque, New Mexico
- Livermore, California

ENERGY STORAGE R&D AT SANDIA

BATTERY MATERIALS

Large portfolio of R&D projects related to advanced materials, new battery chemistries, electrolyte materials, and membranes.

CELL & MODEULE LEVEL SAFETY

Evaluate safety and performance of electrical energy storage systems down to the module and cell level.

POWER CONVERSION SYSTEMS

Research and development regarding reliability and performance of power electronics and power conversion systems.

SYSTEMS ANALYSIS

Test laboratories evaluate and optimize performance of megawatt-hour class energy storage systems in grid-tied applications.

DEMONSTRATION PROJECTS

Work with industry to develop, install, commission, and operate electrical energy storage systems.

STRATEGIC OUTREACH

Maintain the ESS website and DOE Global Energy Storage Database, organize the annual Peer Review meeting, and host webinars and conferences.

GRID ANALYTICS

Analytical tools model electric grids and microgrids, perform system optimization, plan efficient utilization and optimization of DER on the grid, and understand ROI of energy storage.

Wide ranging R&D covering energy storage technologies with applications in the grid, transportation, and stationary storage

DOE OFFICE OF ELECTRICITY ENERY STORAGE PROGRAM

- The goal of the DOE Energy Storage Program is to develop advanced energy storage technologies and systems in collaboration with industry, academia, and government institutions that will increase the reliability, performance, and sustainability of electricity generation and transmission in the electric grid and in standalone systems. The program also works with utilities, municipalities, States, and Tribes to further wide deployment of storage facilities.
- This program is part of the Office of Electricity (OE) under the direction of Dr. Imre Gyuk.

http://www.sandia.gov/ess/

"Assisting Native American Communities in developing adequate and reliable electricity supply and achieving energy sovereignty through energy storage is an important aim of the program"

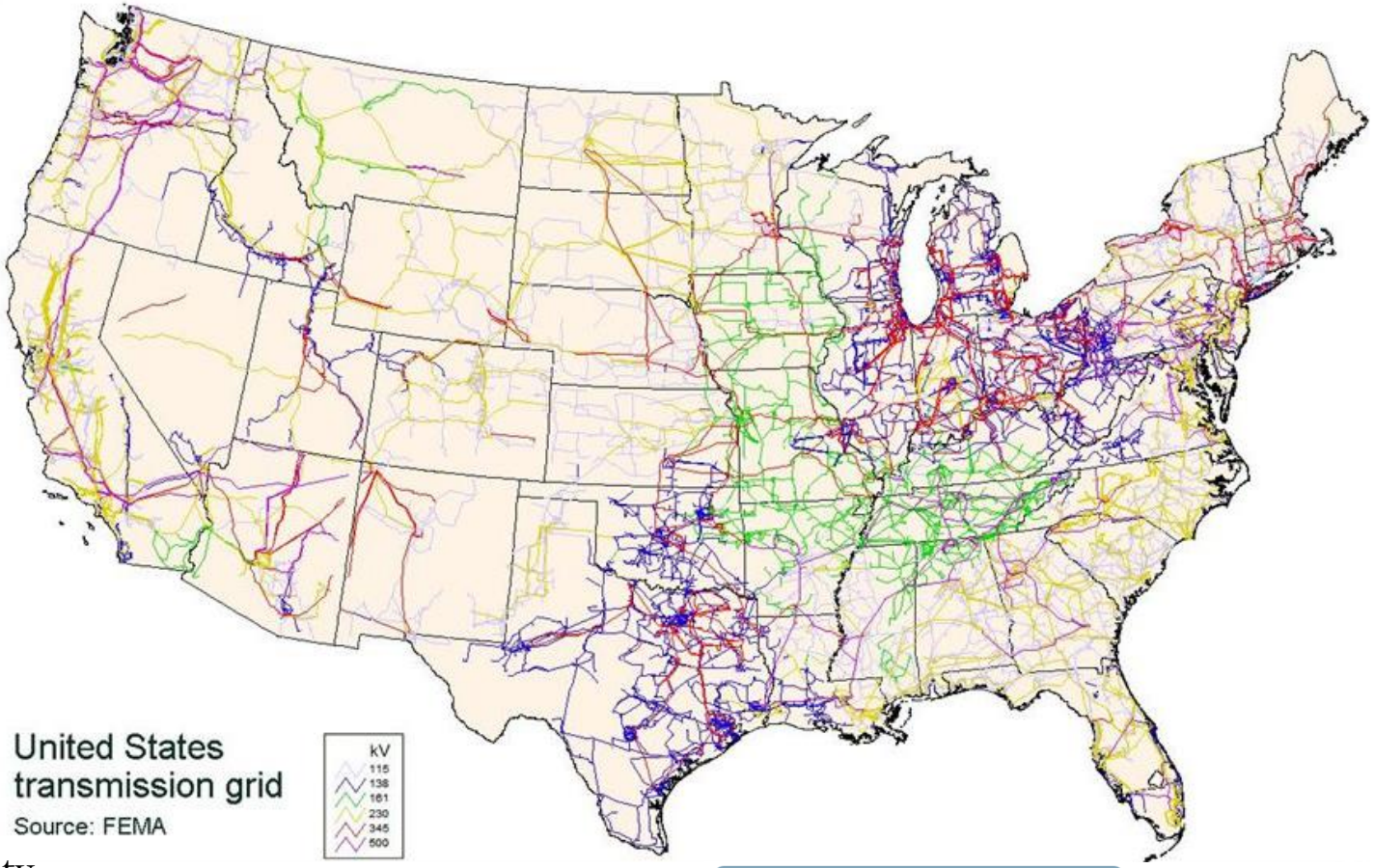
US ELECTRIC INFRUSTRUCTURE – POWER GRID

Common AC voltages

Transmission
- 765kV
- 500kV
- 345kV
- 230kV

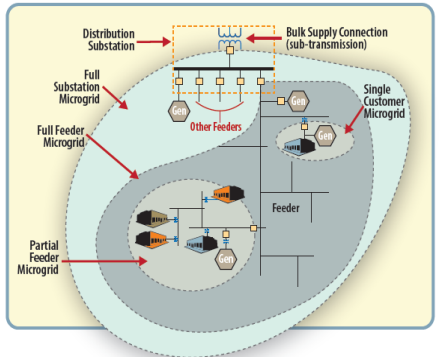
Sub-Transmission
- 69kV
- 30kV
- 15kV

Distribution
- 4kV
- 2kV
- 600V
- 480V
- 240V
- 120V



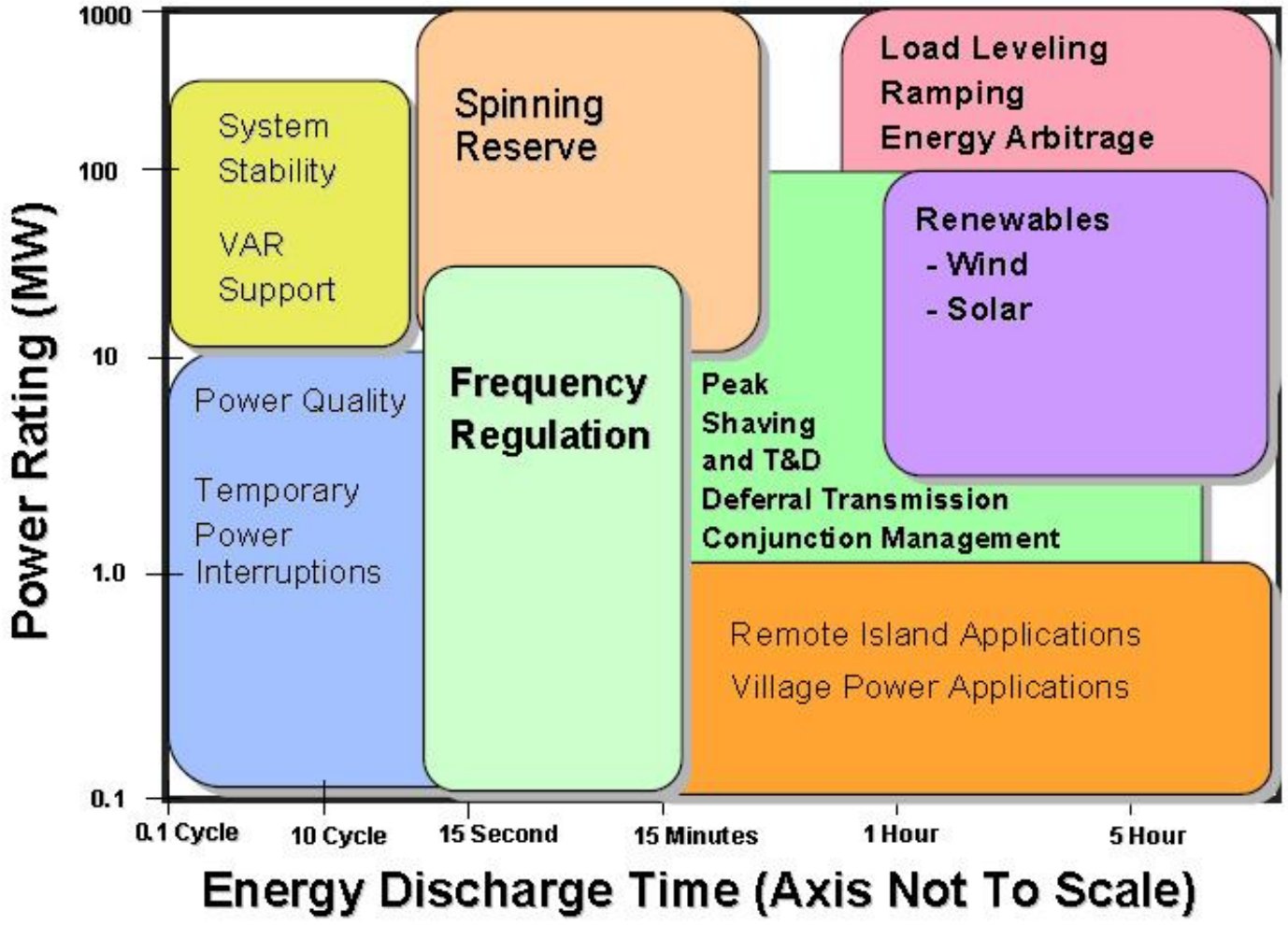
Made up of:

- Over 2 million miles of power lines
- 10s of thousands of generating units totaling over 4 trillion kWh of net generation of electricity
- Millions of transformers, relays, and controls
- 100s of billions of dollars in total investments in transmission and distribution



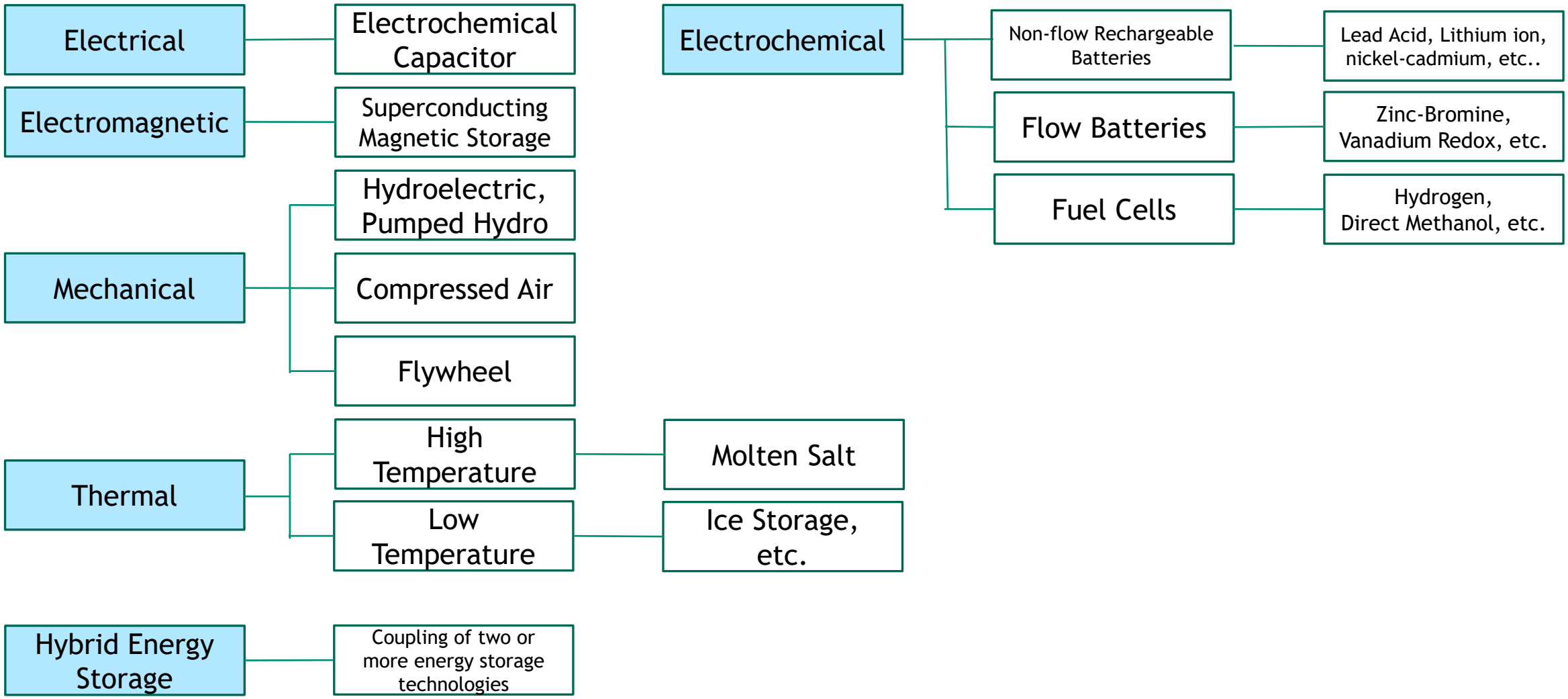
"Microgrids" can connect and disconnect from the main grid.

ELECTRIC GRID POWER AND ENERGY



Source: Electric Power Research Institute

GRID ENERGY STORAGE TECHNOLOGIES

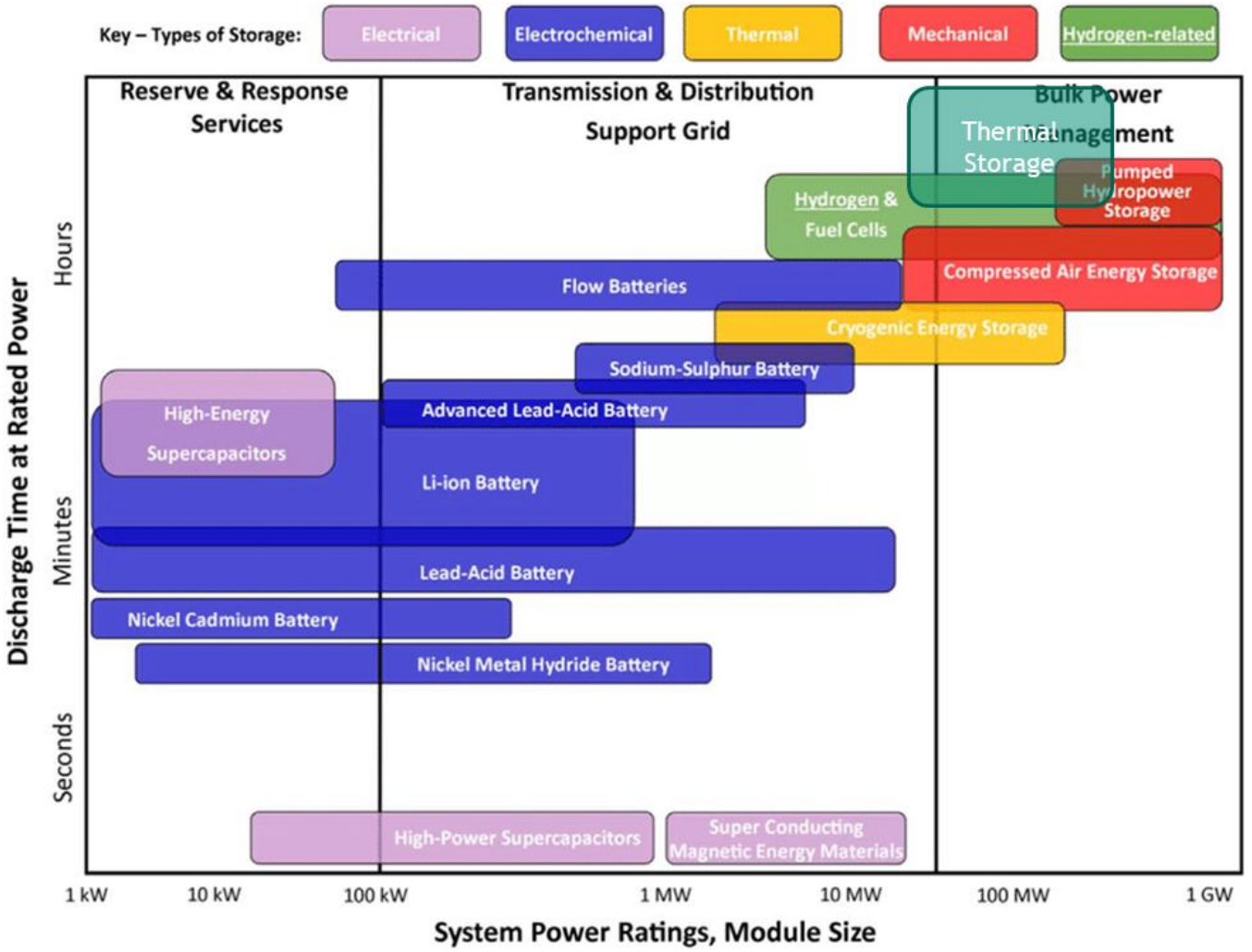


ENERGY STORAGE TECHNOLOGY COMPARISON

Energy

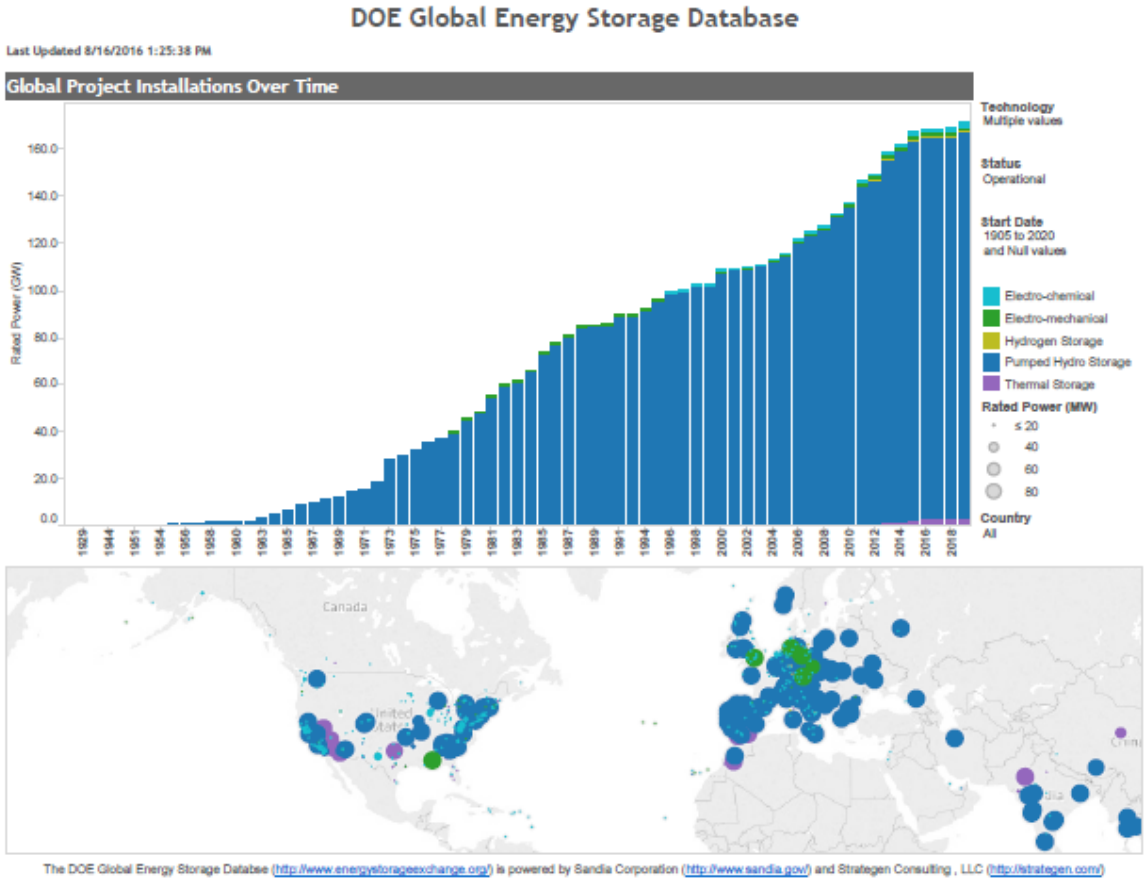
- Pumped Hydro
- Compressed Air Energy Storage
- Batteries
  - Lithium Ion
  - Lead Acid
  - Advanced Lead Carbon
  - Flow Batteries
  - Sodium Sulfur
- Flywheels
- Superconducting Magnetic Energy Storage
- Electrochemical Capacitors

Power



https://www.researchgate.net/figure/Comparison-of-key-type-energy-storage-technologies-in-sense-of-storage-capacity-and_fig1_312870399

DOE GLOBAL ENERGY STORAGE DATABASE



According to market research firm WoodMackenzie, the energy storage market is set to grow to a cumulative deployment of over 85 GW by 2025.

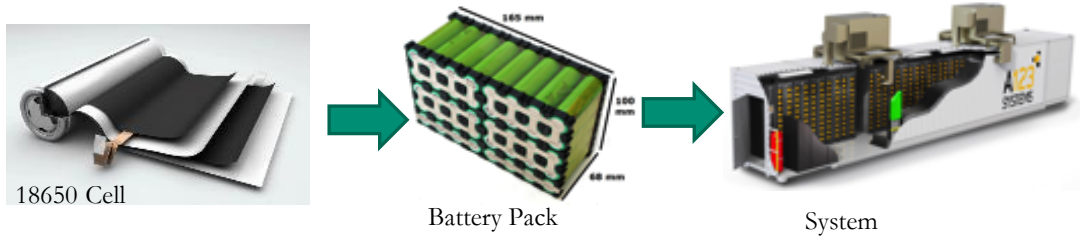
DOE Energy Storage Database
www.energystorageexchange.org

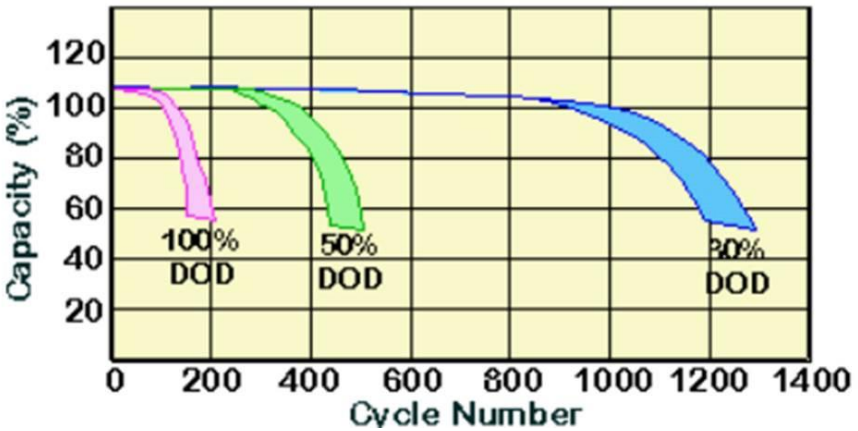
DOE Database (since 2019)

- Over 1,600 Projects
- More than 21 Polices
- Users in over 189 Countries
- 50+ Energy Storage Technologies

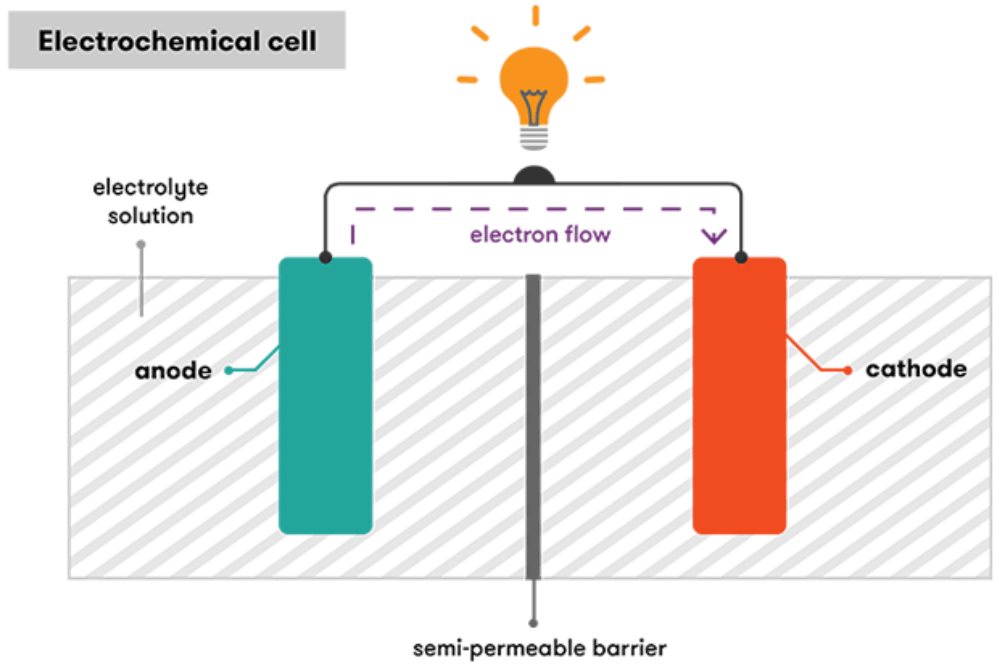
BATTERY STORAGE INTRODUCTION

- A battery is a device that stores chemical energy and converts it to electrical energy
- The chemical reactions in a battery involve the flow of electrons from one material (electrode) to another, through an external circuit
- The flow of electrons provides an electric current that can be used to do work
- Lead acid, lithium ion, nickel cadmium, etc.





Battery cycle life depends on depth of discharge (DOD)



https://www.science.org.au/curious/technology-future/batteries

BATTERY ENERGY STORAGE SYSTEM ELEMENTS

Battery Storage	Battery Management System (BMS)	Power Control System (PCS)	Energy Management System (EMS)	Site Management System (SMS)	Balance of Plant
• Modules • Racks • $/KWh	• Battery Management & BESS Protection	• Bi-directional Inverter • Inverter control • Interconnection / Switchgear • $/KW	• Charge / Discharge • Load Management • Ramp rate control • Grid Stability • Monitoring • $ / ESS	• Distributed Energy Resources (DER) control • Synchronization • Islanding and microgrid control • $ / microgrid	• Transformer/ POC switchgear • BESS container • Climate control • **Fire protection** • Construction and Permitting • $ / project

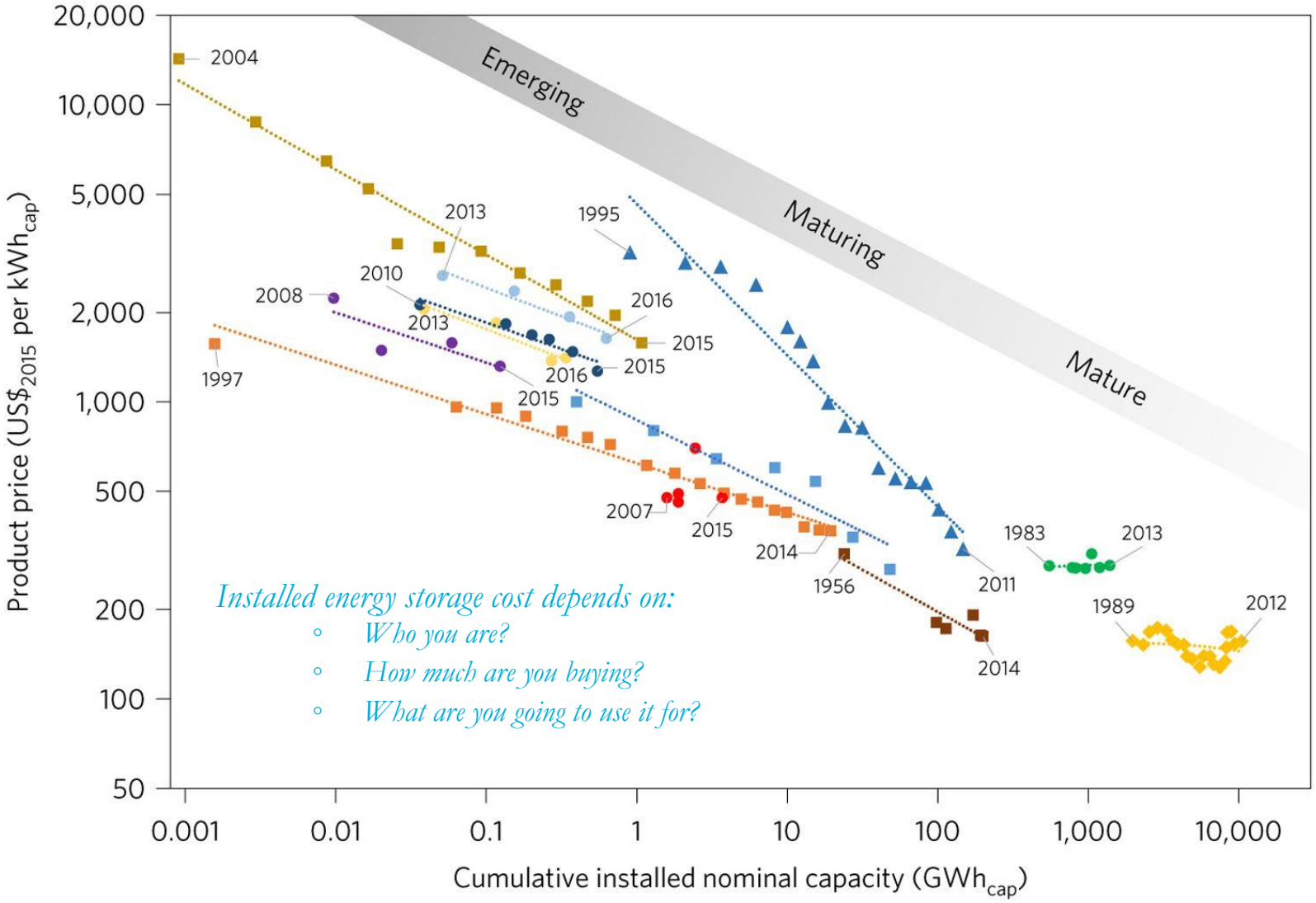


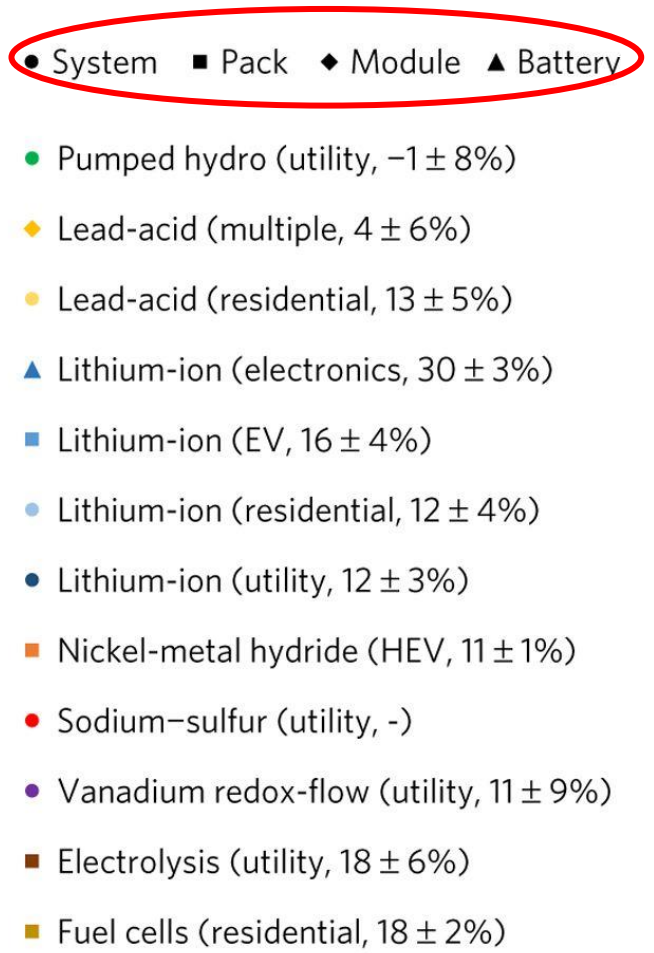


NOTE: Important to have single entity responsible for the ESS integration.

Source: UtilityDrive

ENERGY STORAGE COSTS ($/kWh$_{cap}$) vs. INSTALLED CAPACITY

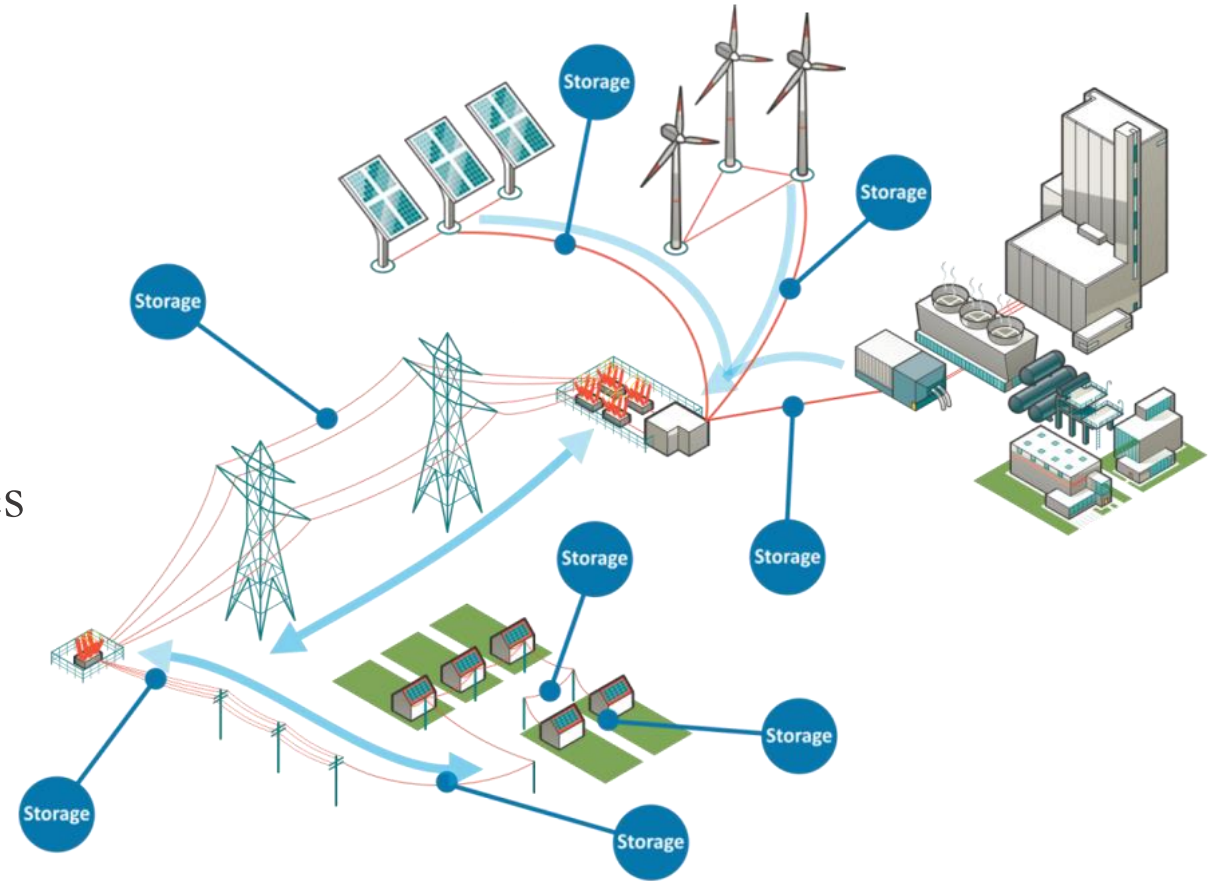




Nature Energy **volume 2**, Article number: 17110 (2017)
https://www.nature.com/articles/nenergy2017110

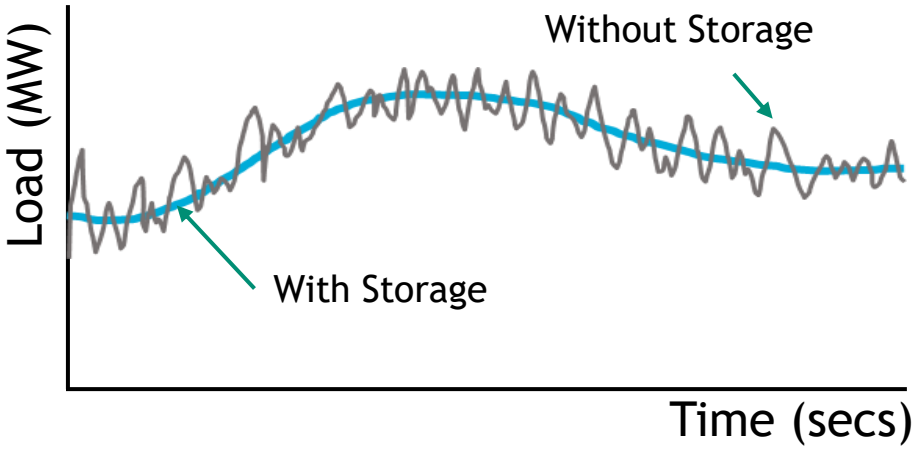
BENEFITS OF ELECTRICITY STORAGE

- Maintain quality power and reliability
- Provide customer services — cost control, flexibility, and convenience
- Improve T&D stability
- Enhance asset utilization and defer upgrades
- Increase the value of variable renewable generation

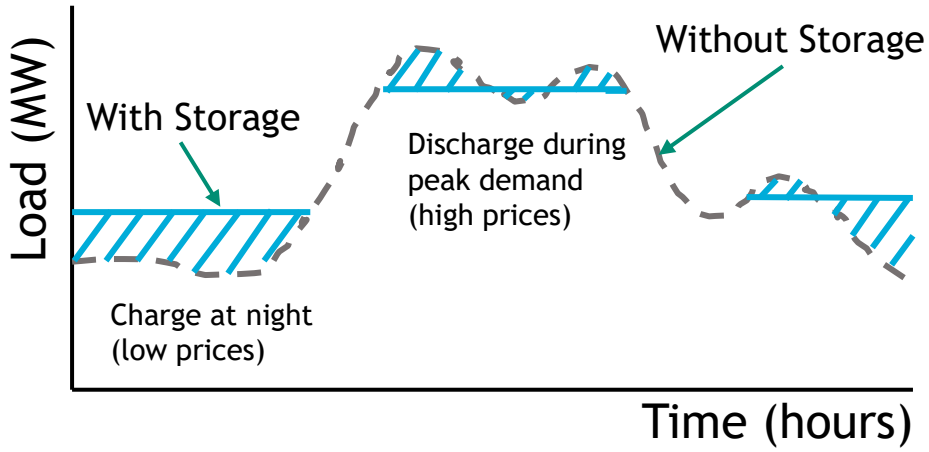


EXAMPLES OF ENERGY STORAGE BENEFITS TO GRID

- Frequency Control
  - Electric utility grid can experience frequency instability
  - If not managed, frequency instability can damage critical components
  - Energy storage injects power into the grid to keep the grid's frequency stable



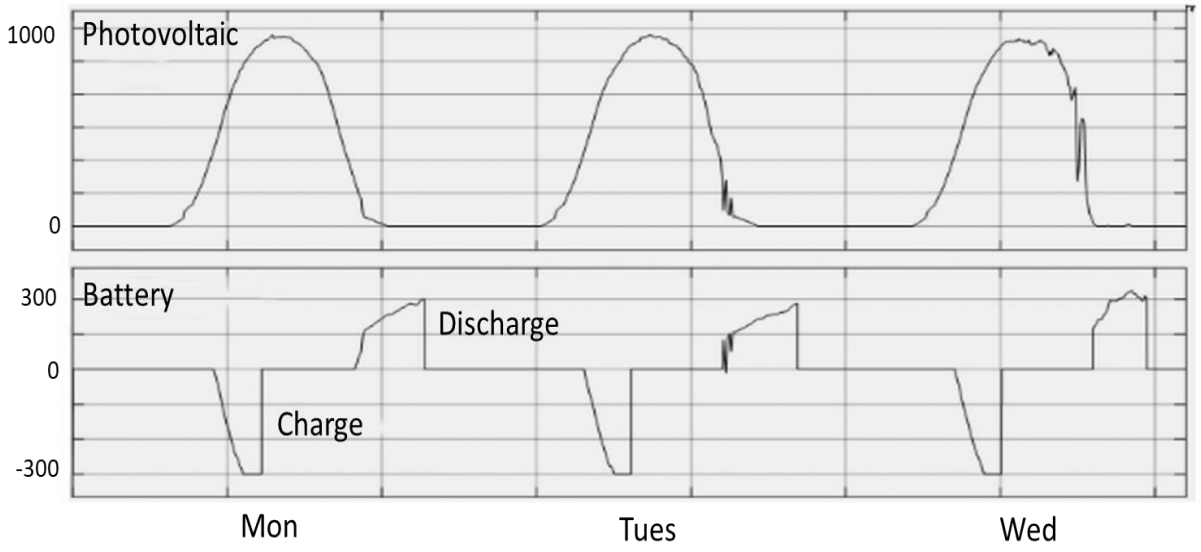
- Peak Shaving
  - Energy storage is charged when electricity rates are at its lowest
  - Energy storage is discharged to avoid paying peak prices during expensive times of the day

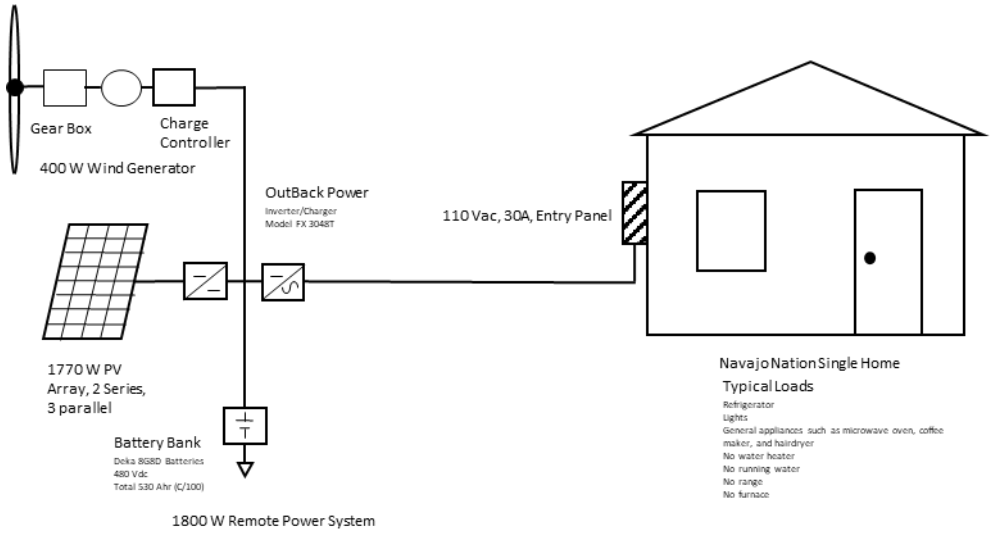


ENERGY STORAGE BENEFITS TO NAVAJO NATION

- Navajo Tribal Utility Authority provides utility services (electricity, natural gas, water, wastewater, and photovoltaic systems) within 27k sq. mi. service territory
- NTUA promotes the use of renewable energy by providing off-grid residential power (640W to 1800W rated turnkey PV-battery-wind turbine systems)

Source: NTUA

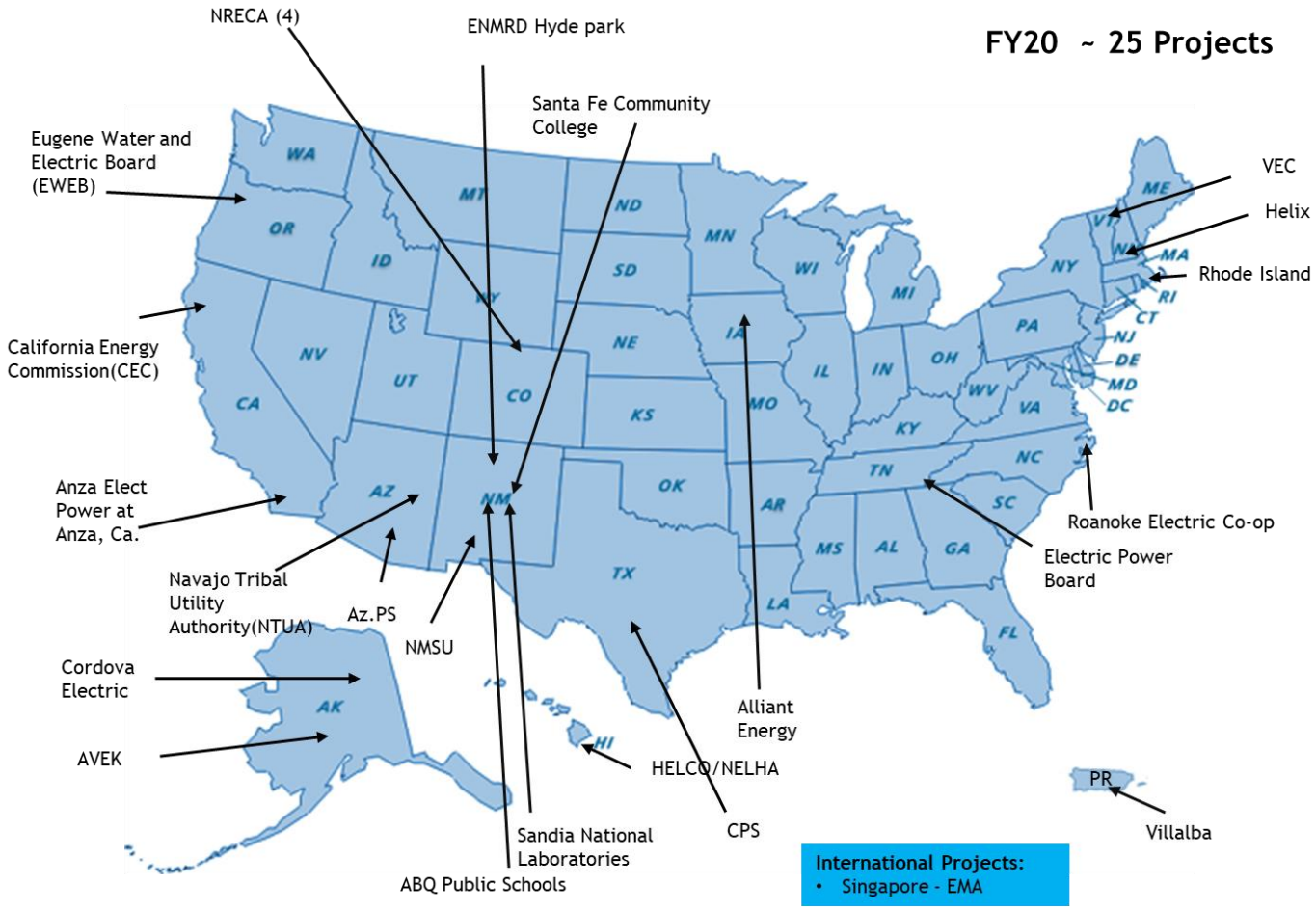




DEMONSTRATION PROJECT OBJECTIVES

What We Do / How we do it

- Work with Utility, Industrial, Commercial, Private, State and International entities to:
  - Provide **third party independent analysis** for Energy Storage Systems (ESS)
  - Support the development and implementation of **grid-tied ESS** projects
    - **Application/Economic analysis**
    - **RFI/RFP development**
    - **Design and Procurement Support**
    - **Commissioning Plan Development**
  - Monitor and analyze operational ESS Projects
    - To maximize return on investment
    - To understand application and stacking
    - To understand performance, reliability and safety
  - Provide Awareness
    - Develop public information programs
    - Demonstrate innovative installations to inform industry of best practices
    - Significant outreach via webinars, seminar presentations, etc.

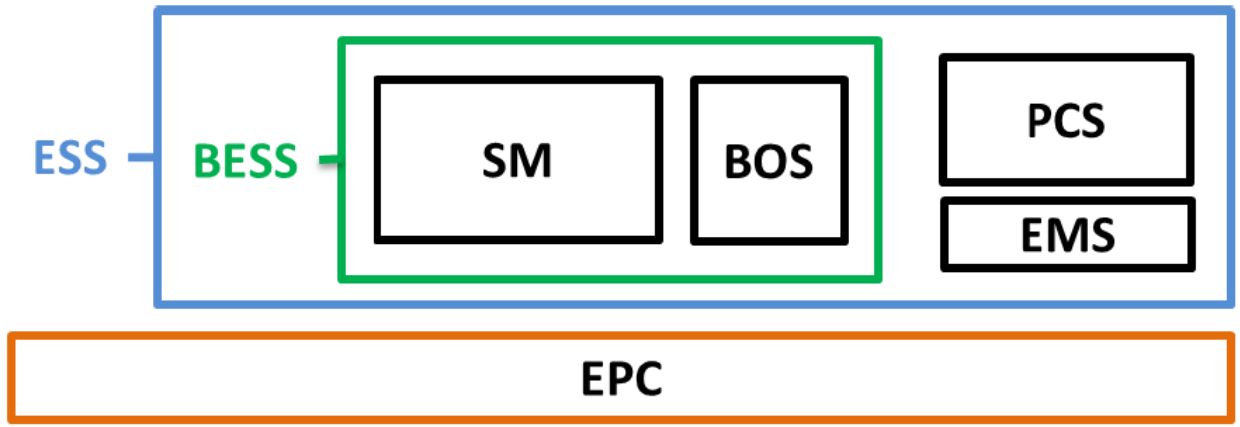


Questions?

Thank You!

BACKUP SLIDES

ENERGY STORAGE SYSTEM COST STRUCTURE



SM **Storage Module**
Rack Level System (DC)

BESS **Battery Energy Storage System**
Containerized System (DC)

ESS **Energy Storage System**
Complete Storage System (AC)

Storage Module (SM)	Balance of System (BOS)	Power Conversion System (PCS)	Energy Management System (EMS)	Engineering Procurement & Construction (EPC)
Racking Frame / Cabinet	Container	Bi-directional Inverter	Application Library	Project Management
Local Protection (Breakers)	Electrical Distribution & Control	Electrical Protection	Economic Optimization	Engineering Studies / Permitting
Rack Management System	Fire Suppression	Connection to Transformer	Distributed Asset Integration	Equipment Procurement / Shipping
Battery Management System	HVAC / Thermal Management		Data Logging	Site Preparation / Construction / Mounting
Battery Module			Communication	Commissioning

Source: Mustang Prairie Energy